U.S. Department of Commerce

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

VOLUME 45 SEPTEMBER 1961 NUMBER 9

Auroral Studies

U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*

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For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Subscription price, domestic $1.50 a year; 75 cents additional for foreign mailing; single copy, 15 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (June 19, 1961).

September 1961 — **Issued Monthly** — **Vol. 45, No. 9**

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COVER: The break-up of aurora, photographed at midnight near College, Alaska, during a joint investigation of short-period auroral fluctuations by the Bureau and the University of Alaska. Studies of auroral phenomena may contribute to an improved basic understanding of the disturbed ionosphere, and thereby may result in more effective techniques of radio propagation. (See "A Study of Auroral Fluctuations," p. 145.) Photo courtesy of the University of Alaska.

A Study of Auroral Fluctuations

AN INVESTIGATION of short-period (6- to 10-sec) auroral fluctuations has been carried out recently by the Bureau's Boulder, Colo., Laboratories and the University of Alaska. Results of this study show that these fluctuations originate in the *E*-region of the ionosphere, and are closely related to magnetic field micropulsations and ionospheric absorption of cosmic noise. The work, performed by W. H. Campbell (NBS), and M. H. Rees (Geophysical Institute, University of Alaska),[1] under the sponsorship of the National Science Foundation and the Office of Naval Research, may contribute to an improved basic understanding of the disturbed ionosphere, and may result in more effective techniques of radio propagation.

The aurora, better known as "northern lights," is a common feature of the night sky in northern latitudes. It may take a variety of forms, ranging from long streaks to curtainlike folds, and vary in color from white to many-colored. There are major changes in auroral intensity corresponding to the 11-yr sunspot cycle, as well as seasonal and nightly variations. In addition, short-period fluctuations (coruscations) of less than several minutes duration are a noticeable feature of auroral displays, reaching a maximum in the pre-dawn hours. Earlier observations by other investigators indicated that these coruscations are accompanied by magnetic field micropulsations and increases in ionospheric absorption of cosmic noise. The present study was conducted to determine the quantitative relationship between these three phenomena.

Measurements

Simultaneous measurements of auroral coruscations, magnetic field micropulsations, and cosmic noise absorption were made from a station near College, Alaska. Useful data were collected on 147 days during the period November 3, 1959, to April 8, 1960.

A "coruscatometer" was designed to measure variations in auroral intensity over large portions of the sky. By registering only the short-period fluctuations, and using a narrow band optical filter, this instrument can be used during moonlight and early twilight. A large area of the sky is sampled to discriminate against false fluctuations caused by motion of auroral forms in and out of the field of view, and to match the "effective view areas" of magnetic and ionospheric absorption measurement instruments. The majority of the observations made with this instrument were of the λ3914 ionized molecular nitrogen emission. A second unit was subsequently developed to permit observations of the λ5577 and λ6300 auroral lines of atomic oxygen.

The magnetic north component of magnetic field micropulsations was measured with a special-purpose loop antenna and a recording system having 3–db points at periods of 4 and 26 sec. Records of ionospheric absorption of cosmic noise, at 27.6 Mc/s, were made available by H. Leinbach of the University of Alaska.

Results

The data indicate that coruscations are a normal part of auroral displays, generally accounting for 5 percent of the λ3914 A total intensity. The dominant period of these fluctuations is between 6 and 10 sec, and their maximum amplitude is reached in the pre-dawn hours. In general, large coruscations may be expected at times of high auroral activity.

The auroral coruscations observed bear a close relationship to both magnetic field micropulsations and cosmic noise absorption. A linear correlation coefficient of 0.6 exists between coruscations and micropulsations, and 0.7 between coruscations and cosmic noise absorption. The peak-for-peak correspondence between coruscations and magnetic field micropulsations indicates these mechanisms are different manifestations of a single phenomenon. The ionospheric absorption measurements, although not capable of resolving any oscillations that might appear, are closely related to magnetic and auroral fluctuation group amplitudes. It seems that variations in the number of electrons reaching the atmosphere from space best explains the relationship between cosmic noise absorption, magnetic field micropulsations, and auroral coruscations.

Height and Electron Density

Measurements were also made to determine both the height at which coruscations originate and the electron densities in the region of coruscation. Data were recorded for a brief time interval during which coruscations covered a large portion of the sky.

Photometric measurements, taken simultaneously at two stations located 225 km apart, were used to determine the height-intensity profile during a period of intense coruscations. In addition, the spectral character of the aurora was also determined with the "IGY Patrol Spectrograph." From this profile, the electron density distribution was found using assumptions of normal auroral processes.

The results of these determinations show coruscations to be a low altitude auroral feature. The height-intensity profile for a particular event early on the morning of April 2, 1960, indicated that the emission occurred in the *E*-region of the ionosphere, with a maximum intensity at 98 km. The associated electron density profile determined for this time showed a sharp peak of 1.1×10^6 electrons/cm^3 at that altitude.

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[1] *For further technical details,* see A study of auroral coruscations, *by W. H. Campbell and M. H. Rees, J. Geophys. Res.* **66,** *41 (1961).*

High-Temperature Heat Capacity of Diamond

RECENT MEASUREMENTS by Andrew Victor of the Bureau have resulted in improved values for the high-temperature heat capacity of diamond. These data, obtained over the range of 323 to 1,073 °K, and accurate to within 0.5 percent over most of the range, join smoothly with other values down to the temperature of liquid hydrogen. An experimental basis is thus provided for the verification of theoretical treatments of diamond-lattice dynamics over a wide range of temperatures.

Diamond-type crystals are of considerable interest for several reasons. Because the "low temperature" behavior of the diamond extends to nearly 1,000 °K, useful data can be obtained with both low and high temperature calorimeters. Also, as the interatomic forces in the diamond lattice are largely covalent, continued investigation should provide further information concerning the directional characteristics of these bonds. Furthermore, silicon and germanium, materials of increasing scientific and industrial importance, possess crystal structures similar to the diamond.

The usual procedure for solving problems concerning diamond-lattice dynamics is to propose a model of the interatomic forces and, employing the elastic constants and first-order Raman frequency shift, to solve a series of equations leading to a calculated value of heat capacity. In order to check the results of such a treatment, reliable values of measured heat capacity must be available.

The last reported measurements of the heat capacity of diamond at high temperatures were made in 1926. The values obtained at that time are believed to be in error because of oxidation of the sample during the measurements. Precautions were taken to prevent oxidation of the diamonds in the present work, and the data obtained by the Bureau are believed to be more reliable than previous results in the temperature range employed.

It is well known that diamonds can be formed by subjecting graphite to extremely high temperatures and pressures. A combination of several types of measurements, including heat capacity, heat of formation, compressibility, and thermal expansion studies on graphite and diamond, permits scientists to predict the temperatures and pressures necessary for this conversion. Calculations based on values of these properties indicate that it should be possible to form diamonds from graphite at temperatures between 1,800 and 2,300 °K and at pressures between 55,000 and 75,000 atm. Synthetic diamonds have been made under these conditions.

Apparatus and Sample

The apparatus [1] consists of a vertical metal tube, the upper end of which is surrounded by an electric furnace and the lower end of which extends into the Bunsen ice calorimeter. Around the lower end of the tube is formed a solid mantle of ice, which in turn is surrounded by ice water. In the bottom of the calorimeter is a pool of mercury, which is connected to an outside reservoir through a small tube. The water-ice-mercury vessel is sealed from the atmosphere, and is insulated by a surrounding bath maintained at the ice point.

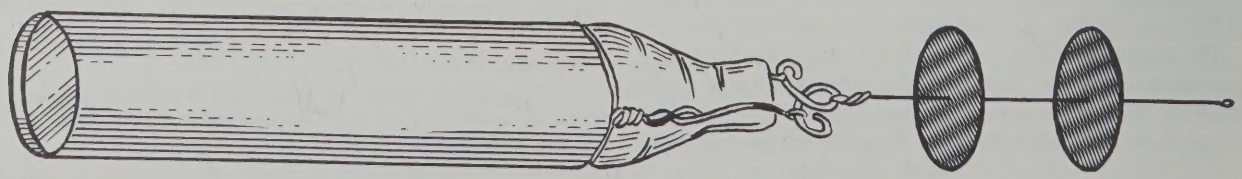
Heat capacity measurements were made on 20.364 g of polished gem diamonds, having an impurity content of less than 0.2 weight percent. The diamonds, after thorough cleaning, were placed in a cyclindrical silver capsule having an internal volume of about 8 cm^3. To prevent oxidation of the diamonds at elevated temperatures, air was removed from the capsule by prolonged pumping, helium at 200 mm mercury pressure was introduced, and the cylinder was sealed. A second silver capsule, used as a blank, was fabricated so as to resemble closely that containing the diamonds.

Measurements were made by first suspending the sample container within the furnace on a wire-pulley arrangement. The temperature of the sample container in the furnace was determined with a platinum resistance thermometer below 873 °K, and with a thermocouple above this temperature.

After heating, the sample was dropped (nearly free fall) into the ice calorimeter, where it melted some ice in cooling. The resulting volume decrease (the water formed is more dense than the ice) drew mercury into the system, the mass of mercury being proportional to the heat evolved by the sample in cooling. By careful weighing of the mercury reservoir before and after each run, the mass of the mercury was determined. The heat equivalence of 1 g of mercury has been established through accurate calibration of the apparatus.

A pneumatic braking device attached to the suspension wire prevented impact of the container with the calorimeter. A gate within the tube was opened only during the drop to prevent transfer of radiation down from the furnace. Circular platinum shields just above the container reduced errors due to heat losses

Container (99.95% silver) used in determining the heat capacity of diamond. The capsule, having a volume of about 8 cm^3, contained 20.364 g of diamonds in a helium atmosphere. The circular shields on the suspension wire prevent errors due to heat losses during cooling.



Right, Bunsen ice calorimeter used in the determination of the high temperature heat capacity of diamond. Sample container (A) is held within electric furnace (B) until thermal equilibrium is reached. The sample is then dropped through tube (C) into the ice calorimeter. Gate (D) is opened during the drop. Heat evolved by the cooling of the sample and container melts some of ice mantle (E). As the water formed by melting has a higher density than the ice from which it was formed, mercury is drawn in from reservoir (F). The mass of the mercury withdrawn is proportional to the heat evolved by the container and contents. The heat content of an empty cylinder was measured to serve as a blank.

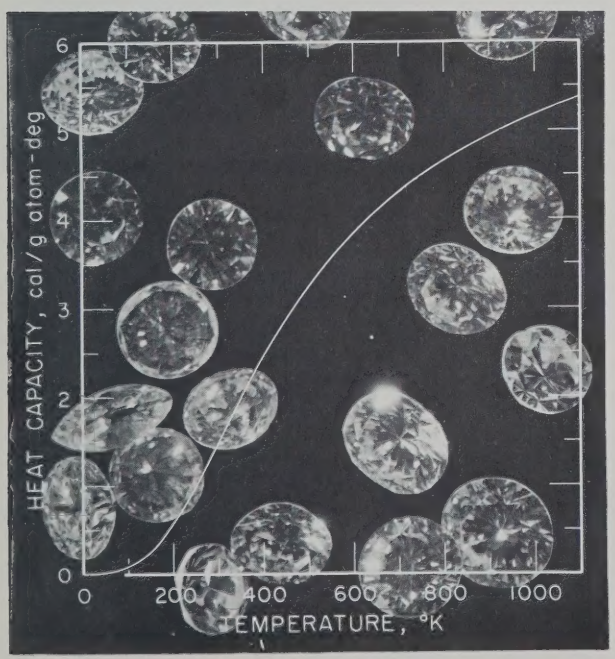
during cooling. The tube through which the sample was dropped was helium-filled to reduce the time required to reach equilibrium in both the furnace and calorimeter.

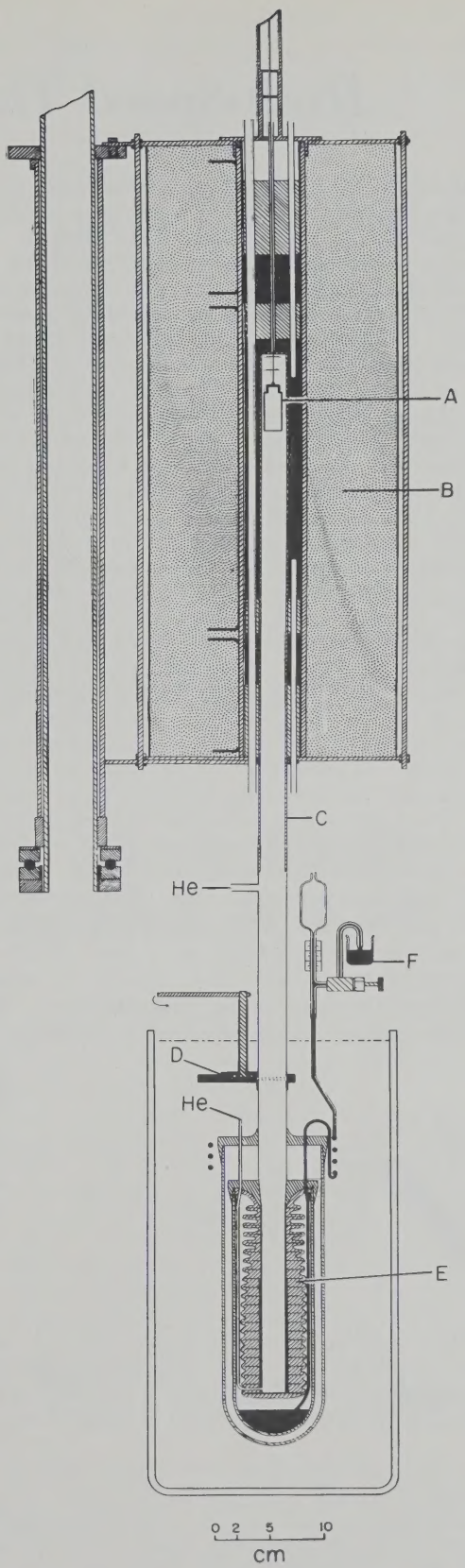
Determinations were made at 50-deg intervals from 323 to 673 °K, and at 100-deg intervals from 673 to 1,073 °K. Replicate runs were made at each temperature except the highest (1,073 °K, at which point a noticeable leak developed in the container), each run having a different heating time to reveal any time-dependence of the data.

Measurements were also made at each temperature with the empty container. These blank determinations provided a measurement of the quantity of heat contributed by the sample container. The heat contributed by the diamonds alone was found by subtracting the value of the container from the total heat measured.

[1] *See* Thermal properties of aluminum oxide from 0° to 1,200° K, *by G. T. Furukawa, T. B. Douglas, R. E. McCoskey, and D.C. Ginnings, J. Research NBS* **57**, *67 (1956) RP2694.*

Below, curve showing heat capacity of diamond as a function of temperature. In the background (greatly enlarged) are some of the specimens used in the study of the high temperature heat capacity of diamond.





High-Speed Three-Color Pyrometer

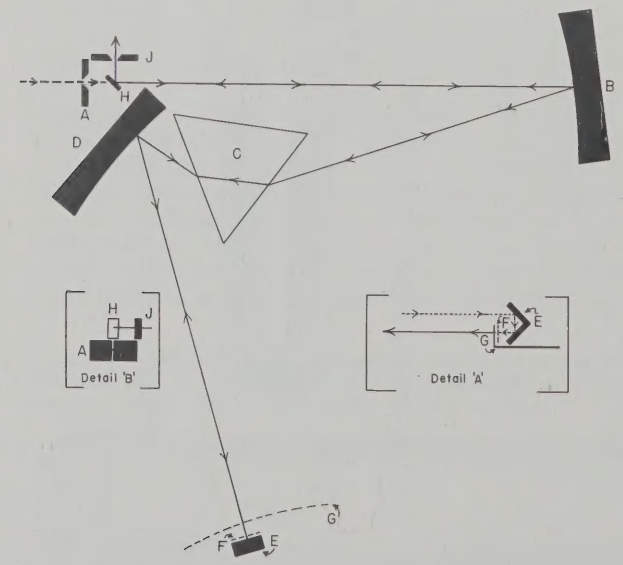
THE PRINCIPLE of a high-speed three-color pyrometer [1] has been demonstrated by a prototype instrument developed by G. A. Hornbeck of the Bureau. The prototype is capable of making 1,000 individual temperature determinations per second in the temperature range 1,000 to 3,000 °C with an uncertainty of about 1 percent. The high-speed characteristics of this pyrometer will be of value in the measurement of temperatures of limited duration. Potential applications include the measurement of the temperature of missile components during firing tests, of ablating nose-cone materials, and with modifications, of exploding wires.

In essence, this instrument forms a spectrum of the radiation from the source, masks out all but the three required wavelengths, and presents these wavelengths to the detector sequentially. When operating at high speed, it is necessary to record the data with an oscilloscope, magnetic tape, or other high-speed recorder.

Certain limitations inherent in one- and two-color pyrometers have been eliminated in this instrument. Brightness temperatures measured with one-color pyrometers can be converted to true temperatures only if the spectral emissivities of the materials being observed are known. To avoid dependence upon knowledge of absolute values of emissivity, two-color or ratio pyrometers have been used in a number of applications. A limitation is once again encountered: the emissivities at the two wavelengths must be identical. Unfortunately, this is not always the case. True temperatures can be obtained through the use of three-color pyrometry, provided the emissivities are a linear function of the wavelengths selected. This criterion is generally true in the near-infrared region of the spectrum. Therefore, this instrument was developed to determine temperatures by measuring the intensities at three different wavelengths.

A unique system for the separation and measurement of three discrete wavelengths was incorporated in this instrument. Radiation from the source of interest passes through an entrance slit and is rendered parallel by a collimating mirror. The beam then passes through a prism and the resulting spectrum is brought in focus with a second mirror. The major feature of

Above, G. A. Hornbeck adjusts the focus of the high-speed ratio pyrometer. To make the instrument more compact (length is about 14 in.), the optical path differs from that shown at left in that the beam passes through the prism four times rather than twice. This device, when combined with a detector-recorder apparatus, is capable of making up to 1000 temperature determinations every second.

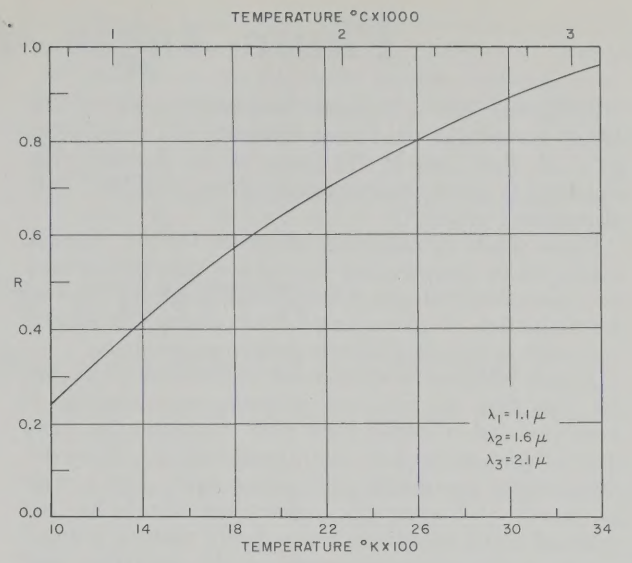


Left, optical system used in the high-speed three-color pyrometer. Light from the source being measured enters through slit "A" and is collimated by mirror "B". Prism "C" creates a spectrum which is focused by mirror "D" on the right-angle mirror "E". From "E" the beam, now vertically displaced, retraces its path to mirror "H", from which it is reflected to a detector. Mask "F" is used to select the desired wavelengths for measurement, and slotted circular frame "G" is rotated to produce a sequential reading of the wavelengths. Details of the right-angle mirror, mask, and chopper are shown in Detail "A", and Detail "B" presents another view of the entrance-slit region.

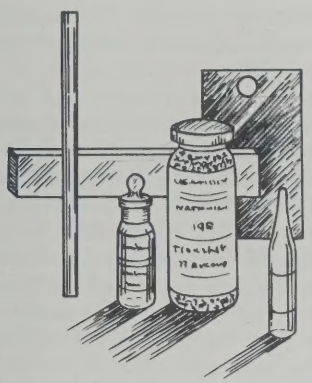
this optical system is a right-angle mirror placed in the vertical plane of the spectral image. As a result of reflection from this mirror, the image is displaced vertically, and retraces its path through the optical system. A mirror placed near the entrance slit reflects the beam to a radiation detector. A mask to pass the selected wavelengths is placed in the path of the beam coming from the right-angle mirror, and a rotating slotted chopper is used to produce a sequential exposure to the detector tube. Because the sensitivity of most fast radiation detectors is wavelength dependent, adjustable attenuating pins are placed in the band pass for each wavelength and set to pass the correct amount of radiation at the time of calibration.

At present, considerable inconvenience is experienced in the mechanical adjustments necessary to change to different wavelengths. However, provision is being made to set the desired wavelengths by dial. A suggested set of wavelengths which would give acceptable sensitivity and avoid atmospheric absorption in the infrared was calculated to be 1.1, 1.6, and 2.1 μ.

[1] A high-speed ratio pyrometer, *by G. A. Hornbeck, to appear in Vol. 3, Temperature, Its Measurement and Control in Science and Industry (Reinhold Pub. Co.).*



Curve showing the variation of R, the ratio of intensities $\frac{I_{\lambda_1} I_{\lambda_3}}{I^2_{\lambda_2}}$, with temperature when the three wavelengths 1.1, 1.6, and 2.1μ are used in the three-color pyrometer. These particular wavelengths are shown by calculation to result in good sensitivity of R to temperature changes, and will be useful for that reason.



STANDARD MATERIALS

Two Radioactivity Standard Materials

Two additional standard samples of radionuclides—iron 55 and promethium 147—are being issued by the Bureau. These two standards,[1] part of a group of 51 now available, result from the Bureau's continual program to establish new and improved radioactivity standards.

Both of the standards have wide applications for medical and industrial laboratory purposes. Iron 55, an electron-capturing nuclide with a half-life of 2.7 years, decays by X-ray and Auger-electron emission directly to the ground state. It is used extensively as a tracer both in biological and industrial research.

Promethium 147 is a pure beta emitter utilized for generation of low-energy X-rays and energy-calibration standards for X-ray and gamma-ray spectrometers. It has a half-life of 2.5 years. In addition to other research applications, this radionuclide is incorporated in luminescence markers and is being considered for use in nuclear batteries.

Both of the standard samples may be ordered under the general licensing provisions of the Atomic Energy Act of 1954. The iron 55 (standard sample No. 4929) and the promethium 147 (standard sample No. 4940) may be purchased for $36.00 and $40.00, respectively. Both samples are in solution form (approximately 3 ml), and have nominal activities of 5×10^4 dps/g. The iron 55 solution contains 1 μg/ml $FeCl_3$ as carrier, while the promethium 147 solution is carrier free. All orders for the radioactivity standards should be addressed to Miss Elizabeth M. Zandonini, Radioactivity Standard Samples, Radioactivity Section, National Bureau of Standards, Washington 25, D.C.

[1] *Standard materials issued by the Bureau are described in* NBS Circular 552, Standard Materials. *This Circular may be ordered for 35 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Up-to-date supplementary inserts, which are issued periodically, are available directly from the National Bureauu of Standards upon request.*

Phase Angle Master Standard

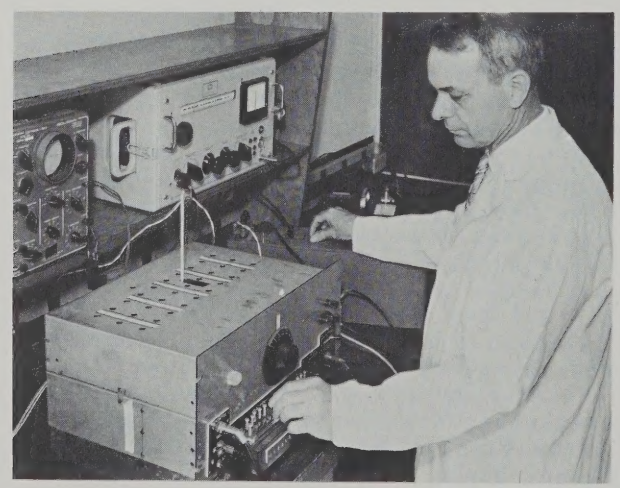
A PHASE ANGLE master standard for use at 400 cycles per second [1] has been designed and constructed by J. H. Park and H. N. Cones of the Bureau. The standard is continuously variable from 0 to 180° with an accuracy of 0.01°.

Phase angle as used here is defined as the quantity employed to measure the time-phase relation between two sinusoidal voltages of the same frequency. Precise determination of phase angle is necessary for solving computer design and missile guidance problems.

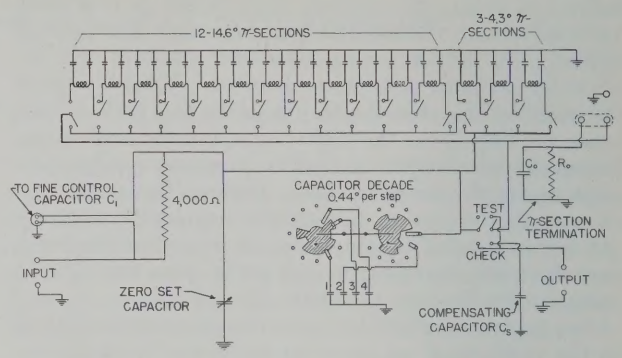
Highly accurate measurements of small phase angles, i.e., less than 3°, and less accurate measurements of somewhat larger angles have been attainable for some time in connection with instrument testing. However, the accurate measurement of phase angle over a wide range and at frequencies higher than 60 c/s has not received much attention until recently when a demand for such measurements arose in the electronic and missile industries.

A number of methods and devices for measuring phase shift have been developed in various laboratories to meet this need. These devices are used to obtain test data in standardizing laboratories. Reference standards with which to compare and coordinate the data accurately must be readily available and must maintain their calibration during shipment among the laboratories. The absolute calibration of such reference standards is most conveniently accomplished by comparison with a thoroughly investigated and accurately calibrated master standard. The Bureau's continuously variable phase shifter is intended primarily for this use.

In planning for the design of a master phase angle standard, the Bureau found that the greatest need is



The Bureau's phase angle master standard is in the foreground. H. N. Cones adjusts the 14.6° π-section mercury contacts. At right is a ratio transformer which is used to obtain a null setting that is shown by the null detector above. The detector is also used in adjusting the π-sections. The oscilloscope at the upper left is used to monitor the 400-c/s frequency.



Schematic wiring diagram for 0-to-180° reference standard phase shifter for 400-c/s operation.

for measurements from 0 to 180° at 400 c/s with an accuracy of 0.01°, if possible. Such a master standard must contain several different magnitudes of phase-shift steps, which can be switched in or out by selector switches, and a continuously variable fine control. The phase shift introduced by each step on any selector switch or by any given change in the fine dial must be independent of the settings on all other switches and dials. Also, it should be possible to compute phase shift for each step from measured values of resistance, capacitance, and inductance.

The design selected consists of twelve 14.6° π-sections and three 4.3° π-sections with switching arrangements so that any desired combination of sections can be connected as a delay line. The input to this line is used as part of an R-C network which incorporates 10 capacitor steps, giving 0.44° phase shift each, and a variable air capacitor for continuous fine control.

The "input," or voltage to be shifted, is connected to a 4,000-ohm noninductive resistor, shunted by a capacitance-remove type variable air capacitor (1,100 to 100 pf), in series with the input to the delay line. A decade set of mica capacitors (0.004 to 0.044 μf) and a zero adjusting capacitance are connected in parallel with the delay line input. A set of 13 single-pole, two-position, mercury-contact switches is arranged to connect any number from zero to twelve of the 14.6° π-sections into this delay line. Also, a set of 4 switches is arranged to connect any number from zero to three of the 4.3° π-sections into the delay line. The delay line is terminated by a fixed impedance consisting of a resistor of 1,000 ohms shunted by a capacitor of 0.0021 μf. An experimental method was devised for accurately adjusting the characteristic impedance of each π-section to be equal to this terminating impedance.

All π-sections must be exactly adjusted to have the same characteristic impedance in order to (1) prevent reflections and (2) make the phase shift put in by the R-C circuit independent of the number of π-sections connected. With these conditions fulfilled, the phase shift of each section was determined experimentally by using an auxiliary phase shifter for intercomparing various sections and a toroidal transformer to check

the 180° point. The phase shift has also been computed from measured values of inductance for each π-section. The results obtained by these two methods agree to within 0.01°, indicating that this phase shifter can be used as a master standard in calibrating other phase shift devices.

Similar phase angle standards for higher audiofrequencies could be designed, but the upper limit in frequency would probably be about 20 kc/s. At higher frequencies, stray capacitance introduced by connecting and switching leads might prove troublesome. It might be feasible to use the same master standard over a frequency range of about 2 to 1 by some readjustments on the π-sections and termination for each frequency.

[1] Phase angle master standard for 400 cycles per second, *by J. H. Park and H. N. Cones, J. Research NBC* **64C** *(Eng. and Inst.), No. 3, 229 (1960).*

NEW DATA CENTER

on Atomic Transition Probabilities and Collision Cross Sections

A center for the collection and evaluation of data on atomic transition probabilities and collision cross sections has been established at the Bureau. The center will compile pertinent data in conjunction with experimental and theoretical investigations being conducted at the Bureau in these areas.

This compilation has been started as part of a research program sponsored by the Office of Naval Research and the Advanced Research Projects Agency. It involves parallel efforts in the two fields of atomic transition probabilities and collision cross sections. A literature search for information on atomic transition probabilities has already been completed. The data center, when fully operational, also will make available information on electron, photon, ion, and atomic collisions of importance in astrophysical or plasma research.

An important objective of the new data center is to collect all literature pertaining to the two fields of interest and to arrange it systematically. The center's collection of experimental and theoretical reprints on cross sections for low-energy electron scattering in gases is complete up to 1960. The bibliography on electron cross sections is being assembled on punched cards to permit rapid retrieval of references. Bibliographies on specific cross sections can thus be compiled completely automatically; those on low-energy scattering and photoionization should be available to interested researchers by the fall of 1961.

A number of transition probabilities are available, especially for the lighter elements and some metals. Since the existing bibliographies in the field of transition probabilities are out of date and incomplete, the Bureau has conducted a comprehensive survey of the published literature to gather and catalogue all pertinent references. This collection, which is now available to research workers in the field, will be used by the Bureau for the preparation of bibliographies and tables. A limited number of specific questions and requests can now be answered with bibliographies on transition probabilities of some of the lighter elements. As soon as possible, complete bibliographies and, at a later date, tables of the "best" available transition probabilities will be published.

The presentation of tables containing numerical data on transition probabilities is a long-range objective of the center. The first ten elements, because of their general importance, will comprise the first of several volumes. The second volume probably will contain the important metals.

A number of references are available for the first ten elements, but results obtained by the same method or by similar methods frequently disagree by as much as a factor of 2. Only a few transition probabilities with errors less than 20 percent are available. A very critical and careful examination of the various results will be necessary for the selection of "best" values and the assignment of error limits.

The lines for each element will be arranged in a group in order of increasing excitation potential within each degree of ionization. A short commentary and a bibliography will accompany each table. The overall arrangement will closely resemble that used in presenting atomic energy levels.[1]

A general method for evaluating transition probabilities, the coulomb-approximation by Bates and Damgaard, will be used extensively in the course of preparing the tables. It will be applied mainly to the lighter elements, where it has given reliable results. Its application is restricted tc certain classes of transitions, however.

It is almost impossible at present to assign numerical relative errors to f-values, especially for those derived by theoretical methods. Preliminary plans call for the classification of each f-value within certain classes to indicate its reliability. Class A would indicate an error less than 20 percent; class B, from 20 to 50 percent; class C, higher than 50 percent, etc. Generally, numerical values will be published only for classes A and B. A reference will be made to those belonging in class C. If, however, as in the case of carbon, no other values are available for the strongest lines, unreliable material will be given explicitly.

The time lag involved in the publication of the results of current research is considerable, and it is hoped that authors will send preprints of their publications to

The Atomic Physics Data Center
National Bureau of Standards
Washington 25, D.C.

Through such communication and by personal contacts, it will be possible to effect a more rapid dissemination of results and, in some cases, to forestall unnecessary duplication of work.

[1] Atomic energy levels, *NBS Tech. News Bull.* **32**, *74 (1948).*

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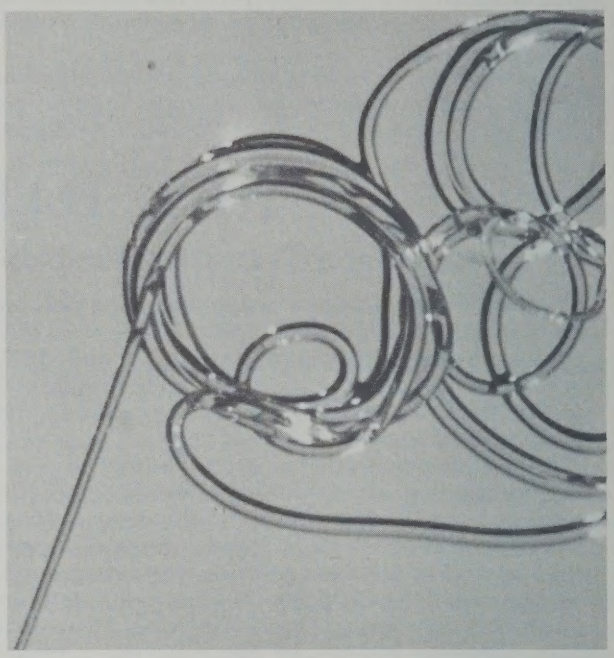
Structural Modificati

TO PROVIDE basic information for the development of structurally modified fibers for use in extreme environmental conditions, the Bureau has been conducting a program of fundamental research on the properties of such systems.[1] In this program efforts will be made to correlate the chemical properties, heat and radiation resistance, and polyelectrolytic behavior of structurally modified fibers with the size, number, and kind of crosslinks and grafts in the polymer fibers.

In preliminary investigations of fiber properties, Stephen D. Bruck has found that unexpected crimping and helical coiling are induced in nylon-6 (homogeneous one-component fibers with round cross sections) by treating the fibers with a swelling agent and, while they are in the swollen state, inserting disulfide and poly(methylene sulfide) crosslinks. Subsequent crimping in the dry state is attributed to heterogeneous crosslinking.

Although intermolecular crosslinking reactions have been employed by various investigators to change the properties of rubber, very little related work has been published on solid, oriented, semi-crystalline structures, such as synthetic fibers. Dissolved polymer systems [2] have been studied, but such preformed networks cannot be readily spun and drawn into fibers. Investigations on crosslinked, solid-state systems, as in the present work, offer an opportunity to study new properties not obtained in ordinary (uncrosslinked) fibers.

Although crimping has not been previously produced in synthetic homofibers by crosslinking, it has been obtained by mechanically crimping homofibers or by the preparation of heterofibers.[3] In the latter process, two polymers of different shrinkage characteristics are combined during spinning into one filament. Among the non-synthetic fibers, wool is known to have natural crimp. This fiber is composed of an orthocortex and a paracortex, each of which has different shrinkage properties. When one shrinks more than the other, crimping is produced.[4]



Above, helical coiling of nylon-6 fiber produced by treating crosslinked fiber with *m*-cresol, a strong swelling agent. (10 ×)

Studies of natural fibers, such as wool and other proteins which are known to have disulfide crosslinkages, have shown that reactive sulfhydril groups may be oxidized to the disulfide linkages with relative ease. This fact seemed to offer a promising approach for the production of chemical reactions leading to similar crosslinking in synthetic fibers. Polyamides (nylon) were therefore selected for the present studies as they possess amide groups which have active hydrogen atoms. These hydrogens may be replaced by various crosslinks under suitable conditions.

Crimping was produced in nylon-6 by introducing two types of intermolecular crosslinks into the solid fiber. In the first method, a large number of sulfhydril groups were chemically implanted into the nylon-6 fiber with subsequent rapid oxidation to disul-

Left, phase photomicrographic assembly coupled with camera for photographing crimped nylon-6 fibers. The Bureau has developed a technique to crimp the synthetic fibers by treatment with a swelling agent and crosslinking with disulfide and poly(methylene sulfide) groups. Dr. Sylvia M. Bailey observes swelling of a fiber.

n of Synthetic Fibers

Above, photomicrographs comparing 2 disulfide-crosslinked nylon-6 fibers. The swollen and wavy single fiber (bottom) was treated with a swelling agent whereas the straight fiber (top) was untreated. (85 ×)

fide crosslinkages. In the second method, some of the sulfhydril groups were reacted with methylene or ethylene dihalide in the presence of a swelling agent to yield poly(methylene sulfide) crosslinks. A higher degree of structural modification and crimping was observed with fibers prepared by this method.

Crimping and coiling are attributed to some structural strain and asymmetry of structure caused by the crosslinking process. It is likely that, during the oxidation process, the sulfhydril groups that are close to the surface of the fiber will be oxidized to a greater extent than those nearer the center. In addition, the easily penetrated points along the fiber will become more densely crosslinked. Accordingly, during subsequent treatment with swelling agents, the inner, less densely crosslinked portions will swell more than the outer, highly crosslinked parts, thus causing crimping of the polymer.

Experiments were carried out to demonstrate the necessity of heterogeneous crosslinking and differential swelling to cause crimping. When some of the crosslinked fibers that had been oxidized by air or dilute hydrogen peroxide solutions were subjected to additional, more prolonged oxidation with peroxide, diminished crimping and coiling were exhibited, apparently because of more uniform distribution of crosslinks throughout the fiber.

The amount of crimping or coiling seems to be influenced by the degree of crystallinity of the fiber. The crystallites, being relatively inelastic, oppose deformations such as coiling. If the swelling takes place in water, which penetrates primarily the amorphous portions of the fiber, the crystallites remain intact and thus maintains a force to counter coiling. In a suitable swelling agent, however, a sufficient number of crystallites are destroyed to permit coiling.

This crystallite effect was further demonstrated when the crimped fibers were treated with *m*-cresol, a strong swelling agent which completely destroys the remaining crystallites. Pronounced helical coiling was observed. Somewhat reduced coiling was observed when the fiber was swollen in a mixture of *m*-cresol and methyl alcohol. Apparently, the judicious use of swelling agents alone or in combination could result in a specific degree of helical coiling.

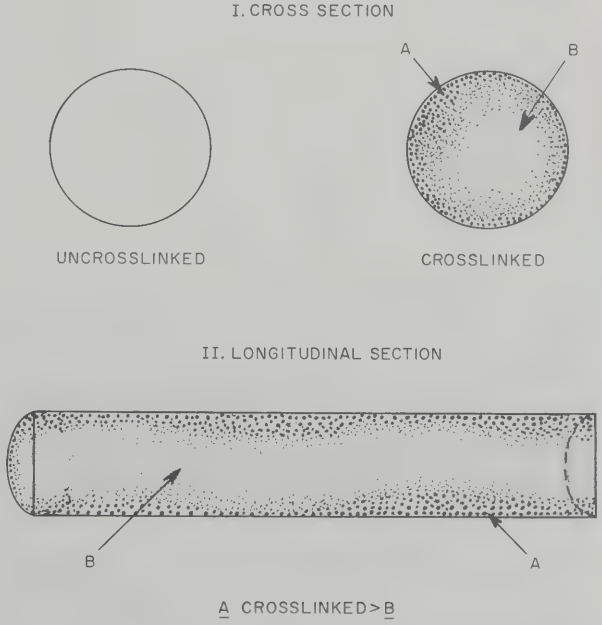
Gradual oxidation throughout the fiber due to air exposure could eventually destroy the crimping and coiling effects. However, it was found that the free unreacted sulfhydril groups can be stabilized by treating the fibers with silver nitrate. Replacement of the hydrogen of the sulfhydril groups by silver then prevents any further oxidation. Blackening of the fiber is a disadvantage of the silver nitrate treatment, but other reagents that would not have this effect could be substituted.

[1] *For further technical information, see* Fiber structure-property relationships: a disulfide-crosslinked self-crimping polyamide, *by Stephen D. Bruck, J. Research NBS* **65A** (*Phys. and Chem.*), (*Nov.–Dec. 1961*); A poly (methylene sulfide) crosslinked polyamide fiber, *by Stephen D. Bruck,* to be published.

[2] *T. L. Cairns et al., J. Am. Chem. Soc.* **71,** *651 (1949)*; *T. L. Cairns et al.; ibid.* **71,** *655 (1949)*.

[3] *W. A. Sisson and F. F. Morehead, Textile Res. Journal* **23,** *152 (1953)*.

[4] *M. Horio and T. Kondo, ibid.* **23,** *373 (1953)*.



Schematic diagram showing nonuniform distribution of crosslinkage along cross section and longitudinal section of symmetrical nylon-6 fiber. This heterogeneity is believed to cause differential swelling, and subsequently crimping and coiling, in the fiber.

Disturbances in a Two-Layer Liquid System

THE BUREAU conducts studies to establish the hydrodynamic laws governing several basic aspects of wave motion, the stability of stratified layers, diffusion phenomena, and the surface activity of solids. This work is part of a long-term project sponsored by the Office of Naval Research. Results of the project aid the Navy Department in using natural hydrodynamic forces to best advantage in ship, weapon, harbor, and breakwater design.

The Bureau's studies are conducted in a specially designed experimental channel which is filled by adding a layer of fresh water above a layer of salt water to simulate conditions sometimes encountered in the ocean near fresh-water inlets, such as a river mouth or a melting coastal ice mass.

This facility was utilized recently in an investigation,[1] by L. H. Carpenter and G. H. Keulegan, of the disturbances produced at the interface of a two-layer liquid system by a body moving horizontally through the upper layer. The disturbances were found to fall into three categories, depending on the relative depths of the layers. A theoretical analysis was made for oscillatory waves produced at the interface when the layers were of equal thickness.

Beginning almost a century ago, numerous investigators studied a succession of standing or progressive waves in heterogeneous liquids with continuously varying density gradients. However, no reference was made to the cause of the disturbance, such as the motion of an object through a stratified medium or the uniform flow of a fluid over a fixed ridge.

During the North Polar Expedition near the coast of Siberia in 1893, the steamship *Fram* found itself in "dead water." In this instance, the resistance of interfacial internal waves initiated by the *Fram's* first attempts at movement prevented it from continuing. This occurrence resulted in an investigation [2] of disturbances of the interface of a two-layer system when a body is towed over the surface.

Studies were also made of the converse problem of a two-layer system moving over a ridge because of differing views concerning the circulation of the Baltic Sea.[3] Some people believe that the circulation is dominated by internal boundary waves resulting from the interaction of the Atlantic tides on the irregular bottom configurations.

More recently, additional studies have been made of liquid flow, including bilayer flow, over a ridge. It was found that internal waves were generated when the ridge projection was small, whereas with enlarged ridges the most important event was the formation of a hydraulic jump.[4] The occurrence of hydraulic jumps (which depend upon velocity, fluid depth, and density difference) in a bilayer or multilayer system is important and has been found to be of significance in meteorology.[5]

In common with the disturbances produced in a nonhomogeneous system by liquid moving over ridges on the bottom or by objects being towed on the surface are phenomena associated with bodies moving through the interior of the medium. The simplest situation is two-dimensional motion of a two-layer system, which was the subject of the Bureau's study.

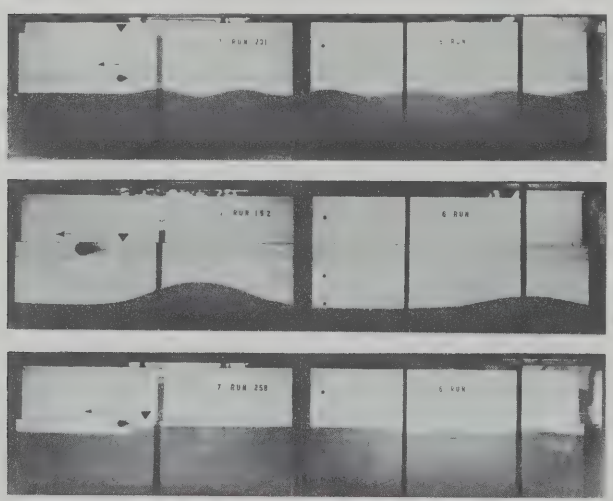
In this study, only the interface deformation was considered. The two fundamental quantities to be established were the wave height and wave length in relation to the speed and position of the body, thicknesses of the layers, and proportionate density difference. It is intended that continuous density gradients be considered in the future.

In the Bureau's experimental set-up, disturbances at the liquid interface were produced by a cylinder moving with constant horizontal velocity in the upper layer. The liquids were initially at rest, and the density difference was small. Runs were made with various depths of the layers, sizes and shapes of the cylinders, and cylinder velocities.

The experimental channel was 26.25 m long, 23.3 cm wide, 57 cm deep, and made up of 21 glass-paneled sections, each 125 cm long. The salt water was mixed and dyed with acid chrome blue and then admitted to the channel to a depth of 2 or 3 cm above the desired level of the interface. The salt water was circulated by a pump to assure uniform density of this layer.

When circulation in the salt water layer had subsided, fresh water was introduced at the center of the channel through a special device which produces as little mixing as possible. A siphon at each end of the channel removed mixed liquid at the interface.

The density distribution was determined with a



The Bureau's experimental channel during an investigation of disturbances due to the motion of a cylinder through a two-layer liquid system. Fresh and salt water were used. The symbol ▲ indicates the water surface. Top: Example of progressive waves produced at the interface between the two liquids when the layers were of equal depth. Center: Example of translation waves of the bottom layer produced when the lower layer was much thinner than the upper layer. Bottom: Example of internal hydraulic jump of the upper layer produced when the lower layer was much thicker than the upper layer.

salinity electrode. The thickness of the transition layer of mixed liquid was 1 to 1.5 cm in all cases, which is small compared with the depths of the fresh and salt water layers.

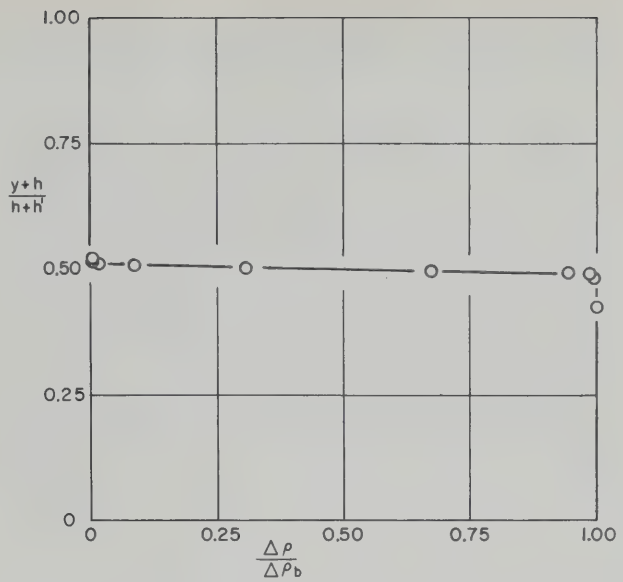
The cylinders used in this study were of three different diameters—2.54, 5.08, and 10.16 cm—and of three different shapes—circular, lenticular, and tear drop. In all cases, the center of the cylinder was placed 30.0 cm from the bottom of the channel.

The cylinders were towed by an electric motor through a variable-speed transmission, a system of pulleys, and two 0.81-mm phosphor bronze towing wires. Four 1.22-mm piano wires under tension acted as guide wires to prevent vertical oscillations of the cylinder. Any velocity from 0 to over 1 m/sec could be selected. Velocity was determined by timing the travel over a distance of 5 m.

The profile of the interface during a run was recorded with three fixed cameras which could be triggered simultaneously or individually. Most of the photographs were taken after the cylinder had traveled about 8 m.

In the present study, three modes of deformation were distinguished. If the layers were of nearly equal thickness, the interface usually yielded a picture of numerous progressive oscillatory waves. If the lower layer was thinner than the upper, an internal solitary wave followed the cylinder. If the upper layer was thinner than the lower, the interface deformed into a hydraulic jump.

Exceptional cases corresponded to low cylinder velocities. The theoretical analysis for disturbances of small amplitude in the first category predicted waves of the type observed, but the observed amplitudes were greater by a factor of two in those cases most nearly satisfying the conditions of the theory. This discrepancy was ascribed to the effect of the wake behind the cylinder.



An example of the vertical distribution of density in the experimental channel. The vertical coordinate y has its origin at the interface; h, depth of saline layer; h', depth of fresh layer; ρ, density of saline layer; $\Delta\rho_b$, difference between densities at bottom and at free surface.

[1] *For further information,* see Disturbances due to the motion of a cylinder in a two-layer liquid system, *by Lloyd H. Carpenter and Garbis H. Keulegan, J. Research NBS* **64C** *(Eng. and Inst.), No. 3, 241 (1960).*

[2] On dead water, Scientific results of the Norwegian North Polar expedition, *by V. W. Ekman, Pt. XV, Christiania, 1904.*

[3] On tidal boundary waves and related hydrodynamical problems, *by N. Zeilon, Kgl. Svenska Vetenskapsakad. Handl.* **47**, *No. 4 (1912).*

[4] Hydraulic jump in a fluid system of two layers, *by C. S. Yih and C. R. Guha, Tellus* **7**, *358 (1955).*

[5] A proposed mechanism of squall lines—the pressure jump line, *by M. Tepper, J. Meteor.* **7**, *21 (1950).*

Folsom to Head NAS-NRC Building Research Committee

The National Academy of Sciences-National Research Council has appointed Dr. Richard G. Folsom, President of Rensselaer Polytechnic Institute, Troy, N.Y., as Chairman of the Special Advisory Committee of the Building Research Advisory Board for the Study of Building Research at the National Bureau of Standards.

Dr. Folsom, an eminent administrator, educator, and engineer, was from 1953 to 1958 Professor at the University of Michigan and Director of its Engineering Research Institute; his professional affiliations include the American Society of Mechanical Engineers, American Society for Engineering Education, American Rocket Society, American Institute of Chemical Engineering, and the Institute of Aerospace Sciences.

The study of building research at the Bureau is being conducted under the auspices of BRAB at the request of NBS Director, Dr. Allen V. Astin. The Special Advisory Committee has been established for the purpose of reviewing NBS functions and activities relating to building research and, on the basis of such review and consideration of the needs and opportunities for building research in the United States, recommending a mission or relationship which NBS could most appropriately assume in this area. The proposed study was recommended by the special committee of the National Academy of Sciences that reported to the Secretary of Commerce in March 1960 on the role of the Commerce Department in science and technology.

The members of the Special Advisory Committee are Dr. A. Allan Bates, Vice President, Research and Development Laboratories, Portland Cement Association, Skokie, Ill.; Dr. Harold B. Gores, President, Educational Facilities Laboratories, Inc., New York, N.Y.; Peter B. Gordon, Vice President, Wolff and Munier, Inc., New York, N.Y.; Harry Hansen, Director, Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Cincinnati, Ohio, and Associate Director, Bureau of State Services, USPHS; Dr. Haldon A. Leedy, Director, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill.; Robert F. Legget, Director, Division of Building Research, National Research Council, Ottawa, Canada; John S. Parkinson, Director, General Research, Johns-Manville Products Corporation, Manville, N.J.; William H. Scheick, Executive Director, American Institute of Architects, Washington, D.C.

It is anticipated that the study will be completed within a year's time. Those interested in learning more of the activities of the Committee should contact Robert M. Dillon, Executive Director, Building Research Advisory Board, National Academy of Sciences-National Research Council, 2101 Constitution Avenue, Washington 25, D.C.

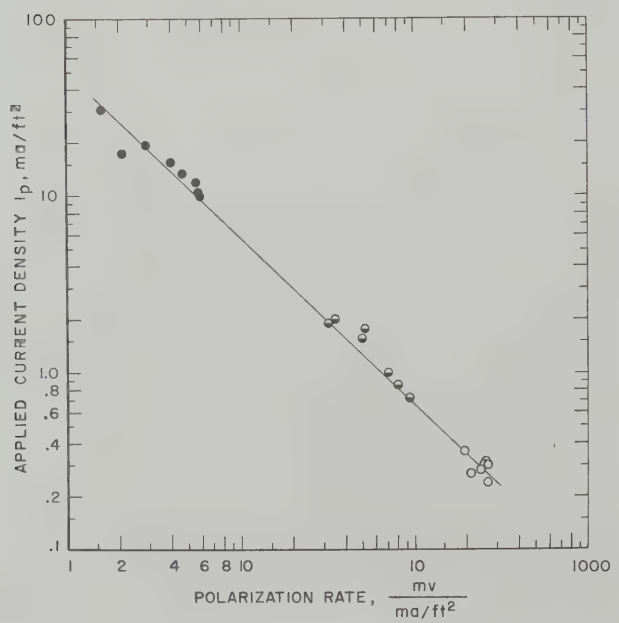
Study of Coatings Formed by Cathodic Protection

COATINGS that form on steel being cathodically protected from salt-water corrosion effectively reduce the amount of externally applied current required, according to a recent Bureau experiment. Polarization measurements made near the end of a period of almost 5 years of exposure showed that protection was maintained, even though the protective current ultimately was reduced more than 200-fold. Experimental data derived from the study may be applied to certain types of corrosion problems.[1]

Because corrosion of iron and steel in salt water is an electrochemical phenomenon, cathodic protection is frequently employed to block the corrosion reaction. In this method, positive metal ions are prevented from passing into solution by direct current which flows from an auxiliary anode toward the surface of the metal. As increments of current are applied, the potential changes, and recorded data on the current-potential relationship show the rate of polarization. A "break" in the polarization curve marks the point at which the applied current has effectively blocked most of the corrosion current.

The present study was undertaken by W. J. Schwerdtfeger to investigate the effects of coatings that form during cathodic protection. He was assisted in the latter part of the work by R. J. Manuele, professor of chemistry at La Plata University, Argentina, and a guest worker at the Bureau.

In the experiment, three specimens of cold-rolled steel, 0.5 in. in diameter and 18 in. long, were exposed to tap water to which had been added 3 percent by weight of sodium chloride. The rods, vertically suspended in separate open jars each containing 17 liters of the solution, were protected against corrosion at the water line by plastic tape. Specimen No. 1 was permitted to corrode freely in order to serve as a control. Except for controlled interruptions near the end of the exposure period, specimen No. 2 was continuously protected by a sacrificial zinc anode, and specimen No. 3 by direct current from a copper oxide rectifier. The water in the jars was maintained at a level within the taped areas of the specimens.



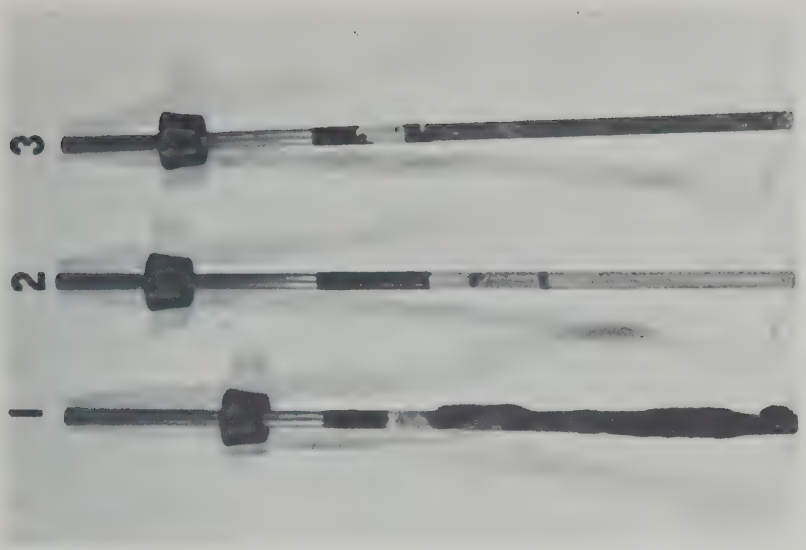
The relationship between the applied current density (*Ip*) at the "break" in the cathodic polarization curves and the polarization rate found from the same curves is shown for three specimens. Specimen No. 1 (●) was allowed to corrode freely in this NBS experiment; No. 2 (◒) had scratches made in the protective coating; No. 3 (○) was fully coated.

During the first months of exposure, the protective current density of 5.0 ma/ft² required to protect specimen No. 3 was several times the current density of the zinc to specimen No. 2. But from the 33d to the 57th month of exposure, the current to specimen No. 3 was progressively lowered by reducing the applied rectified voltage to a value which held the potential of the specimen to about −0.77 v, with reference to a saturated calomel electrode. Eventually this technique permitted the current to be reduced to 0.02 ma/ft², a large reduction from that required at the beginning of the experiment.

At the end of 54 months, cathodic polarization curves were obtained on all three specimens. The superiority of the coating formed on specimen No. 3 to that of speciment No. 2 was indicated by small current values at the break in the cathodic curve and correspondingly high polarization rates. Spread in the data obtained for specimen No. 2 was chiefly due to increasing rates of corrosion caused by scratches purposely made in the coating toward the end of the exposure period. The high corrosion rate of the unprotected specimen was indicated by large current values and low polarization rates.

Anodic polarization curves were also obtained for the specimens, and from the two sets of data corrosion currents were calculated and used to compute theoretical weight losses. The values thus found agreed reasonably well with actual weight-loss measurements made after the specimens were cleaned. Specimen No. 1 lost 11,835 mg of metal during the long exposure period while specimen No. 3 lost only 35 mg, with 12 mg of this total going into solution through pores in the coating during an unprotected period of 29 days.

The quality of the coating formed on specimen No. 3 as indicated by the polarization data was verified at the end of the experiment. It was not only more compact and heavier than the coating on specimen No. 2 but also more adherent. Spectrochemical analysis showed the coatings on both specimens to be primarily calcium carbonate, although they contained some silicates. The eventual superiority of the coating on



Steel specimens used to investigate the coatings formed by cathodic protection against corrosion. In the experiment, specimen No. 1, used as a control, was allowed to corrode freely; specimen No. 2 corroded only at areas scratched in the coating while without protective current for 36 days; specimen No. 3 received practically complete protection because of the coating while without protective current for 29 days.

specimen No. 3 was attributed to the lowering of the protective potential to the optimum value of −0.77 v.

Results of the study show that polarization techniques can be used to measure the corrosion, if any, occurring within the pores or cracks of protective coatings. Further, the apparent straight-line logarithmic relationship between the polarizing current and the polarization rate (at the break in the curve) appears useful for estimating the corrosion rates of other metals and alloys in various aqueous media. In practical situations where corrosion rates are controlled by anodic polarization, the anodic data could be used in the logarithmic relation.

[1] *For further technical details, see* "Coatings formed on steel by cathodic protection and their evaluation by polarization measurements," *by W. J. Schwerdtfeger and Raul J. Manuele, J. Research NBS* **65C** *(Eng. and Instr.), No. 3, 171 (1961).*

Time Adjustment in WWV and WWVH Standard Broadcasts

On August 1, 1961, at 0000 UT, the Bureau advanced the phase of the time signals broadcast from radio stations WWV and WWVH by 50 msec. Such step adjustments are made when necessary to follow the variations in Universal Time (UT–2) so that the time signals remain within about 50 msec of UT–2.

The time signals are maintained on a uniform basis by means of atomic frequency standards. Departure of the time scale from UT–2 reflects a small but perceptible fluctuation in the speed of rotation of the earth.

Similar changes were made simultaneously on the other standard frequency broadcasting stations which have been coordinating their transmissions since early 1960 under an agreement between agencies of the United Kingdom and the United States.

Coordination helps provide a more uniform system of time and frequency transmissions throughout the world, needed in the solution of many scientific and technical problems in such fields as radio communications, geodesy, and the tracking of artificial satellites.

Participating in the project are the Royal Greenwich Observatory, the National Physical Laboratory, and the Post Office Engineering Department in the United Kingdom, and, in the United States, the U.S. Naval Observatory, the Naval Research Laboratory, and the National Bureau of Standards. This program follows previous cooperative efforts of these agencies to achieve uniformity and simplification in procedures.

The transmitting stations which are included in the coordination plan are GBR and MSF at Rugby, England; NBA, Canal Zone; WWV, Beltsville, Md.; and WWVH, Hawaii.

Atmospheric Research Reported

The improvement of radio communications between earth-earth and earth-satellite stations depends upon a better understanding of the regions through which signals are propagated. As part of its radio propagation program, the Bureau's Boulder, Colo., Laboratories conduct theoretical and experimental investigations of the ionosphere, the upper atmosphere, and the troposphere over a wide portion of the frequency spectrum. The results of some of these programs were reported by members of the Ionospheric Research and Propagation Division, the Radio Systems Division, and the Upper Atmosphere and Space Physics Division at the spring meeting of the International Scientific Radio Union-Institute of Radio Engineers. The meeting was held at Georgetown University, Washington, D.C., May 1–4, 1961.

E- and F-Region Research

The *E*- and *F*-regions of the ionosphere are important to communications in that they cause reflection of radio waves, thus permitting propagation beyond the horizon. The Bureau is conducting a wide variety of research programs designed to improve the understanding and use of these regions in effective communications.

Experimental work, carried out during the past 3 years with a transmitting station at Long Branch, Ill., a midpoint ionosonde at Shickley, Nebr., and the Colorado receiving sites of the Bureau, revealed inconsistencies in the published literature concerning the relationship of sporadic-*E*, observed at vertical incidence, with that recorded on VHF oblique-incidence circuits. These discrepancies are largely explained if the different types of sporadic-*E* are considered separately and the effect of antenna gain in the very-high-frequency (VHF) circuits is properly evaluated.

Further results based on fading and direction-of-arrival measurements substantiate a theory that intense ionization centers exist for the type of sporadic-*E* which provides TV–DX. A multiple reflection point experiment has also produced evidence of a moving "front" of sporadic-*E* some 200 km wide. This work, performed by a group including E. K. Smith, J. F. De Gregorio, K. Kildahl, and J. W. Finney, was reported on at the meeting by Mr. Finney.

Hope I. Leighton gave a paper entitled "World-wide sporadic-*E* occurrence as observed at vertical incidence during the IGY." This paper dealt with the more detailed study of the geographic variation of sporadic-*E* made possible by the increased number of vertical incidence ionospheric sounding stations in operation during the International Geophysical Year.

An analysis of sporadic-*E* types recorded at thirteen stations, nine near the 75th meridian, showed that the summer maximum was largely due to *c*-type sporadic-*E*. The boundary between the auroral and temperate zones was considered for different sopradic-*E* types and found to be less sharply defined than indicated by earlier measurements. The Japanese summer maximum found by earlier Bureau research was particularly intense during the IGY. In addition, a tongue from this maximum was discovered, reaching all the way to West Africa. In Siberia, annual incidence was found to be several times less than what would have been expected. Data, including considerably more detail than was available before IGY for the southern hemisphere, were also put in such form that Whitehead's theory of dependence of sporadic-*E* on the horizontal component of the earth's magnetic field could be tested.

William S. Hough presented additional information on the effect of sunspot cycle on the *E*-layer. The studies discussed were based on vertical incidence sweep-frequency observations of the ionosphere taken on about 1100 nights during 1953–1954 and 1957–1958, using an ionosonde with a low frequency limit of 50 kc/s.

Robert Cohen discussed the nature of "equatorial slant sporadic-*E*," and presented the results of work done by K. L. Bowles, Wayne Calvert, and himself. "Equatorial slant sporadic-*E*" is a slanting trace configuration prevalent on ionograms obtained near the magnetic equator. It is a daytime phenomenon and always occurs in association with "equatorial sporadic-*E*." It appears at about the critical frequency of the regular *E*-layer traces and at a height of about 100 km; the virtual height increases with increasing frequency in a nearly linear fashion. Some speculation has ascribed this trace to a scattering layer located below the *E*-layer, or to sporadic-*E* irregularities between 120 and 200 km in height.

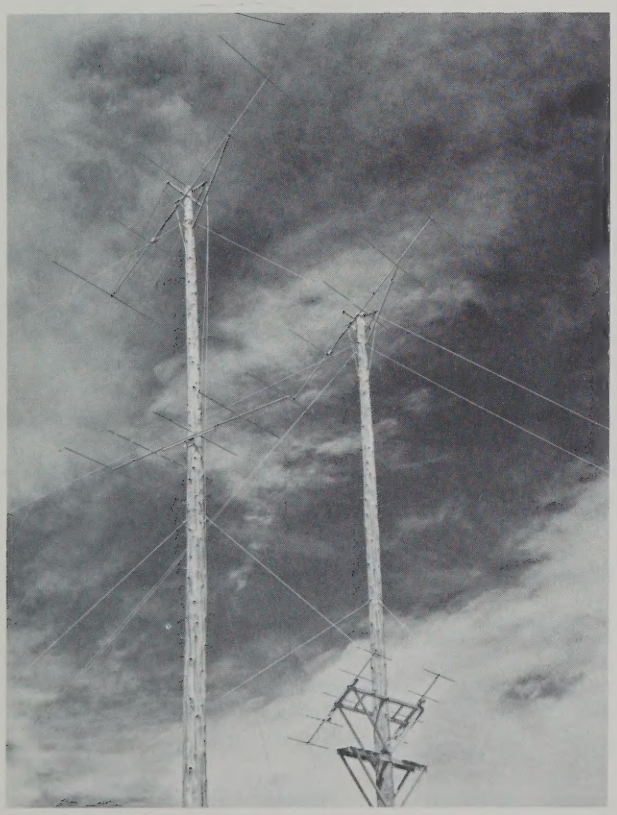
Based on studies using special antenna arrays and a C-4 ionosonde (for vertical incidence ionospheric soundings) at Huancayo, Peru, it appears that the equatorial slant sporadic-*E* configuration is a "radio illusion." This illusion is caused by echoes in the east-west plane from *E*-layer irregularities alined with the earth's magnetic field and embedded in the equatorial *E*-layer at a height of about 105 km. The refraction mechanism which produces the slanted trace is analogous to that which produces one form of "equatorial spread-*F*" configuration. Using a process of ionogram-synthesis, it is possible to reproduce many features of the equatorial slant sporadic-*E* and equatorial sporadic-*E* complex observed on the Huancayo ionograms.

Certain properties of the equatorial ionosphere can be determined by this technique, including the characteristics of the equatorial *E*-layer, such as thickness, the height of the equatorial sporadic-*E* layer relative to the regular *E*-layer, and the thickness of the equatorial sporadic-*E* layer. An important conclusion made from these studies is that the variations of current in the equatorial electrojet are relatively coherent over distances of hundreds of kilometers along the magnetic equator.

Wayne Calvert reported on "The interpretation and synthesis of certain spread-*F* configurations appearing on equatorial ionograms," the results of work done in collaboration with Dr. Cohen. There are a number of spread-*F* configurations observed on ionograms obtained near the magnetic equator. Two of these, equatorial spread-*F*, and temperate latitude spread-*F*, had been described earlier. A third configuration was noted to be apparently anomalous in that it resembles temperate latitude spread-*F*. This third configuration is now recognized as arising from the same small-scale, magnetic-field-alined irregularities that produce equatorial spread-*F*, so that the equatorial spread-*F* category should be broadened to include it.

A process of ionogram-synthesis was developed as follows: Based upon refraction in a plane, parabolic *F*-layer, the time delay in propagation to a scattering irregularity arbitrarily situated in the vertical east-west plane through the ionosonde has been calculated as a function of frequency. This procedure enables the simulation of the ionogram that would be obtained from such an irregularity. By superposing the responses from such single-scattering centers distributed in the vertical east-west plane, it is possible to reproduce many features of equatorial spread-*F* observed on Huancayo ionograms.

Vertical delta antenna used in connection with an ionosonde for vertical soundings of the ionosphere.



This process of ionogram-synthesis provides a new technique for determining the height of patches of small-scale irregularities in the *F*-region, the horizontal distance of the patches from the ionosonde in the east-west plane, the thickness of the patches, their east-west extent, and the east-west component of their drift velocity.

Other Topics

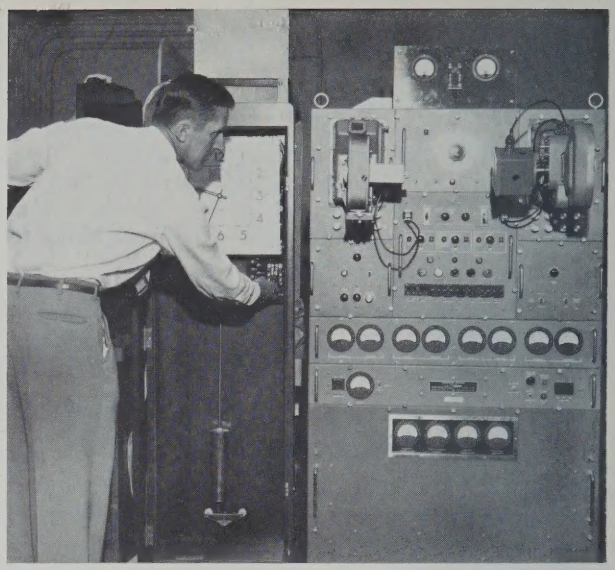
C. A. Samson presented results of studies in collaboration with R. F. Linfield (formerly NBS) on weather and sferic phenomena. Data obtained from measurements made in Colorado and Kansas during a period of severe thunderstorm and tornado activity in May 1960 were analyzed with respect to variations of certain sferic characteristics as meteorological conditions changed over a wide area. An interesting correlation with a TIROS I cloud photograph was obtained. It appears that information obtained by using the "EPHI" direction-finding system can provide a rather sharp delineation of the zones of severe weather activity.

W. L. Taylor discussed "Radiation field characteristics of lightning discharge in the band 1 kc/s to 100 kc/s," dealing with studies of the ground-wave portion of atmospheric waveforms to determine various characteristics of the radiation field from lightning discharges. Sixty-nine representative waveforms were selected from 1021 atmospherics from twenty-one thunderstorms in the Oklahoma and north Texas area. The average amplitude and phase spectra for several groups of atmospherics having distinguishable characteristics were presented from 1 kc/s to 100 kc/s. Various relationships of the atmospherics, involving total radiated energy, peak field strength, first half-cycle length, spectral amplitude peak, and frequency of spectral peaks were considered.

Conclusions from these studies indicate that "normal" type atmospherics, which compose 86 percent of the total, are predominantly of positive initial polarity, have spectral peaks near 5 kc/s, and have well-defined relationships between the parameters first discussed. All "other" types of atmospherics are predominantly of negative initial polarity, have spectral peaks from less than 1 kc/s to 18 kc/s, and have no well-defined relationships between the various parameters.

C. J. Chilton spoke on "The phase variations of 16 kc/s transmissions from Rugby, England, as received in Boulder, Colorado." This paper was concerned with a study of one year's measurement of the daily phase variation of the 16 kc/s transmission, GBR, as received along a 7500 km path at Boulder, Colo. He discussed the results of observations of the received signal as shown in daily, seasonal, and abnormal variations, and described some of the effects of solar flares, cosmic-ray bursts, and magnetic disturbances on the phase.

Carlene Lilley presented a paper on studies done in collaboration with J. R. Johler. Experimental techniques and equipment are now available which can simultaneously record at several locations the transient electromagnetic field signatures from thunderstorm sources and, at the same time, precisely locate the source of the sferic. These data, coupled with special



The ionosonde (right) is the principal instrument used for measuring electron density and height in vertical soundings of the ionosphere. John J. Pitts adjusts the clock controls so that the programing of the ionosonde conforms to the WWV time signal.

mathematical techniques, permit the deduction of the effective conductivity of the ground over the path of sferic propagation at low radiofrequencies. Results of the analysis suggest that the techniques employed can be used to evaluate the reflection and transmission properties of the lower ionosphere.

Lillie C. Walters presented the results of a study of modern analysis techniques, made in collaboration with J. R. Johler, which avoids two main analytical difficulties inherent in computations of the diffraction of electromagnetic waves, particularly at low frequencies. By using a large-scale electronic computer, Hankel functions of complex argument of the first and second kind, and of order one-third, two-thirds, and complex order, are calculated by numerical integral methods and then used with iteration to solve Riccati's differential equation. This permits the evaluation of the amplitude and phase of the wave diffracted in the vicinity of the earth for various altitudes of source and receiver by means of the summation of the series of residues.

A. C. Wilson presented a paper concerning studies by himself and Herman V. Cottony on "Observed directions of arrival of ionospherically scattered signals." Working with the NBS electronically-scanned antenna [1] simultaneous observations were made of the arrival of 40.92 and 40.88 Mc/s signals along a path, NBS Long Branch, Ill., to Boulder, Colo., with the transmitter at Long Branch. A 50-deg transmitting antenna beamwidth was used at 40.92 Mc/s, a 5-deg beamwidth at 40.88. Deviations from the great-circle path direction were observed at both frequencies. These were much greater at 40.92 Mc/s due to the 50-deg transmitting antenna beamwidth. Records also indicated that instantaneous amplitude is a function of the direction of arrival and that amplitudes vary with time. The effect of propagation by meteor bursts was illustrated by samples of signals using this method.

[1] High-resolution scanning antenna, *NBS Tech. News Bull.* **44**, *155 (1960)*.

Geomagnetic Storm Forecast by NBS

High-frequency radio communications were disrupted for three days by a severe geomagnetic storm starting July 13; however, ample warning of its advent by the Central Radio Propagation Laboratories at Boulder, Colo., permitted adequate precautions to be taken at communications centers both in this country and on the high seas.

First indication of the storm came just before 1700 hr Universal Time on July 11, when sensitive instrumentation at Boulder recorded a disturbance on the sun in the form of a large outburst at a frequency of 108 Mc/s. Simultaneously, a large sudden phase anomaly was noted in long-wave signals from the Canal Zone, and a short-wave fadeout occurred in radio transmissions from Washington, D.C.

The presence of a major flare on the sun was immediately verified by the Sacramento Peak Observatory in New Mexico. Another laboratory at Fort Davis, Tex.—part of the large solar observations network cooperating with the Boulder Laboratories in their radio warning service—reported that an enhancement in all frequencies had been observed on its solar radio spectrograph, indicative of a major solar event.

The Boulder Laboratories immediately notified the Bureau's radio propagation field stations at Fort Belvoir, Va., and Anchorage, Alaska, which provide radio disturbance forecasts to the North Atlantic and North Pacific areas, respectively. Within an hour, radio warnings were flashed to inform all ships at sea and other users of high-frequency radio communications of the impending disturbance.

Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Volume **45,** No. 8, August 1961. 15 cents. Annual subscription: $1.50, 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Basic Radio Propagation Predictions for November 1961. Three months in advance. CRPL–204, issued August 1961. 15 cents. Annual subscription $1.50, 50 cents additional for foreign mailing. Avaliable on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards
Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.
Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.
Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.
Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Section B. Mathematics and Mathematical Physics, Volume **65B,** No. 3, July–September 1961.

Theory of an accurate intermediary orbit for satellite astronomy, J. P. Vinti.

Note on the "baffled piston" problem, F. Oberhettinger.

Some results on non-negative matrices, M. Marcus, H. Minc, and B. N. Moyls.

Probability inequalities of the Tchebycheff type, I. R. Savage.

Section C. Engineering and Instrumentation, Volume **65C,** No. 3, July–September 1961.

Prediction of symptoms of cavitation, R. B. Jacobs.

Heating and cooling of air flowing through an underground tunnel, B. A. Peavy.

Stress-corrosion cracking of the AZ31B magnesium alloy, H. L. Logan.

Coatings formed on steel by cathodic protection and their evaluation by polarization measurements, W. J. Schwerdtfeger and R. J. Manuele.

Calibration of inductance standards in the Maxwell-Wien bridge circuit, T. L. Zapf.

Calibration of loop antennas at VLF, A. G. Jean, H. E. Taggart, and J. R. Wait.

Location of the plane of best average definition with low contrast resolution patterns, F. E. Washer and W. P. Tayman.

Influence of temperature and relative humidity on the photographic response to Co^{60} gamma radiation, M. Ehrlich.

Nonperiodical

Capacities of stacks in sanitary drainage systems for buildings, R. S. Wyly and H. N. Eaton, NBS Mono. 31 (1961), 35 cents.

Technical Notes

The following Technical Notes are available from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (Order by PB number.)

Mean electron density variations of the quiet ionosphere 4—June 1959, J. W. Wright, L. R. Wescott, and D. J. Brown, NBS TN40–4 (PB151399–4) (1961) $1.50.

Collisions of liquid drops with liquids, O. G. Engel, NBS TN89 (PB161590) (1961) $1.00.

Determination of the K fluorescence yield of argon by proportional-counter spectrometry, C. Godeau, NBS TN91 (PB161592) (1961) 50 cents.

On the climatology of ground-based radio ducts and associated fading regions, E. J. Dutton, NBS TN96 (PB161597) (1961) $1.75.

A fixed frequency, 9.1 Gc, field intensity recording receiver with extremely narrow bandwidth, R. W. Hubbard and J. V. Cateora, NBS TN107 (PB161608) (1961) 75 cents.

Data reduction instrumentation for radio propagation research, W. E. Johnson, NBS TN111 (PB161612) (1961) $1.00.

Publications in Other Journals

Vapor phase gamma-radiolysis of azomethane, L. J. Stief and P. Ausloos, J. Phys. Chem. **65,** 887–881 (1961).

Electron interferometer studies of iron whiskers, H. A. Fowler, L. Marton, J. A. Simpson, and J. A. Suddeth, J. Appl. Phys. **32,** No. 6, 1153 (June 1961).

Changes in dentures during storage in water and in service, J. B. Woefel, G. C. Paffenbarger, and W. T. Sweeney, J. Am. Dental Assoc. **62,** No. 6, 643–657 (June 1961).

Solar disturbances and radio communication forecasts, J. F. Brockman, Sky and Telescope **XXI,** No. 6, 322–326 (June 1961).

Dissociation constant of the protonated acid form of 2-amino-2-(hydroxymethyl)-1, 3-propanediol [tris (hydroxymethyl) aminomethane] and related thermodynamic quantities from 0 to 50°, R. G. Bates and H. B. Hetzer, J. Phys. Chem. **65,** 667–671 (1961).

Hyperfine structure and isotope shifts in the 2537–A line of mercury, W. G. Schweitzer, Jr., J. Opt. Soc. Am. **51,** No. 6, 692–693 (June 1961).

Long-distance one-hop F_1 propagation through the auroral zone, L. H. Tveten, J. Geophys. Research **66,** No. 6, 1683–1684 (June 1961).

Resonators for millimeter and submillimeter wavelengths, W. Culshaw, IRE Trans. Microwave Theory and Tech. **MTT–9,** No. 2, 135–144 (March 1961).

Paramagnetic substances for nuclear orientation, R. P. Hudson, Prog. in Cryogenics **3,** 99–127 (1961).

A five-attribute system of describing visual appearance, D. B. Judd, Am. Soc. Testing Materials Spec. Tech. Pub. No. 297 (1961).

Circumferentially uniform electroplating of tube bores, J. P. Young and H. I. Salmon, Plating **48,** No. 7, 783; 787–8 (July 1961).

Solar flare effects in the *F* region of the ionosphere, R. W. Knecht and K. Davies, Nature **190,** No. 4778, 797–798 (May 1961).

Age to indium resonance for D–D neutrons in heavy water, V. Spiegel, Jr., and A. C. B. Richardson, Nuclear Sci. and Eng. **10,** No. 1, 11–15 (1961).

Magnetic properties and optical absorption spectrum of K_2ReCl_6, J. C. Eisenstein, J. Chem. Phys. **34,** No. 5, 1628–1648 (May 1961).

Convective circulation in water induced by evaporation cooling, W. G. Spangenberg and W. R. Rowland, Phys. of Fluids **4,** No. 6, 743–750 (June 1961).

Photoionization heating in the *F* region of the atmosphere, D. C. Hunt and T. E. Van Zandt, J. Geophys. Research **66,** No. 6, 1673–1682 (June 1961).

Identification of fiber blends by infrared spectroscopy, M. K. Wharton and F. H. Forziati, Am. Dyestuff Reptr. **50,** No. 14, 33–36 (July 1961).

Residual losses in a guard-ring micrometer-electrode holder for solid-disk dielectric specimens, A. H. Scott and W. P. Harris, 1960 Annual Report, Conference on Electrical Insulation, Natl. Acad. Sci.-Natl. Research Council, 11–17 (1961).

Calculations of the neutron age in water and heavy water for D–D sources, J. W. Cooper, Nuclear Sci. and Eng. **10,** No. 1, 1–10 (May 1961).

Magnetic susceptibility of cerous magnesium nitrate, R. P. Hudson and W. R. Hosler, Phys. Rev. **122,** No. 5, 1417–1420 (June 1961).

Use of gaussian orbitals for atoms-in-molecules calculations, M. Kraus, J. Chem. Phys. **34,** No. 2, 692–693 (February 1961).

Measurement of minority carrier lifetime in SiC by a novel electroluminescent method, G. G. Harman and R. L. Raybold, J. Appl. Phys. **32,** No. 6, 1168–1169 (June 1961).

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Publications (Continued)

Absolute measurement of W for Po^{210} alpha particles in air, nitrogen, and carbon dioxide, Z. Bay, P. A. Newman, and H. H. Seliger, Radiation Research **14,** No. 5, 551–565 (May 1961).

Comparative *p*H measurements on papers by water extraction and glass electrode spot tests, J. H. Flynn and L. E. Smith, Tappi **44,** No. 3, 223–228 (March 1961).

The structure of the monoclinic form of sodium tetrametaphosphate tetrahydrate, H. M. Ondik, C. H. MacGillavry, and S. Block, Acta. Cryst., **14,** 555 (1961).

A comparison between theoretical and experimental data on phase velocity of VLF radio waves, J. R. Wait, Proc. IRE **49,** No. 6, 1089–1090 (June 1961).

A diffraction theory for LF sky-wave propagation, J. R. Wait, J. Geophys. Research **66,** No. 6, 1713–1724 (June 1961); An additional note, J. R. Wait and A. M. Conda, J. Geophys. Research **66,** No. 6, 1725–1729 (June 1961).

Mass spectrometric study of cyanogen and cyanoacetylenes, V. H. Dibeler, R. M. Reese, and J. L. Franklin, J. Am. Chem. Soc. **83,** 1813–1818 (1961).

An analysis of errors in the calibration of electric instruments, F. L. Hermach, Communication and Electronics, 1–6 (May 1961).

Energy levels and magnetic dipole transitions in the $4p^4$ ground configuration of singly ionized atomic bromine (Br II), W. C. Martin and J. L. Tech, J. Opt. Soc. Am. **51,** No. 6, 591–594 (June 1961).

An improved structure determination for vinyl fluoride, D. R. Lide, Jr. and D. Christensen, Spectrochim. Acta **17,** 665–668 (1961).

Incoherent scattering by free electrons as a technique for studying the ionosphere and exosphere: Some observations and theoretical considerations, K. L. Bowles, pp. 223–243 of AGARDograph **42,** The upper atmosphere above *F*2-maximum. North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development, Avionics Panel. Papers presented at the Symposium of the Ionospheric Research Committee, Paris, France, May 1959.

A *p*H standard for blood and other physiologic media, V. E. Bower, M. Paabo, and R. G. Bates, Clin. Chem. **7,** No. 3, 292 (June 1961).

Evidence on the laminar nature of the exosphere obtained by means of guided high frequency wave propagation, R. M. Galley and W. F. Utlaut, Phys. Rev. Letters **6,** No. 11, 591–594 (June 1, 1961).

Comparison of the ionization produced in air by alpha particles near 5 mev and by beta particles, Z. Bay and P. A. Newman, Radiation Research **14,** No. 5, 566–572 (May 1961).

A century-old razor, S. J. Rosenberg, Metal Progress, 94–96 (1961).

Some applications of Hardy's formula in Brownian motion (Abstract), A. Ghaffari, Am. Math. Soc. Notices **8,** No. 54, 238 (June 1961).

On the classical approximation in the statistical theory of mass spectra, H. M. Rosenstock, J. Chem. Phys. **34,** 2182 (1961).

Optical calibration of vibration pickups at small amplitudes, V. A. Schmidt, S. Edelman, E. R. Smith, and E. Jones, J. Acoust. Soc. Am. **33,** No. 6, 748–751 (June 1961).

Superconductivity of Nb_3Sn in pulsed fields of 185 kilogauss, V. D. Arp, R. H. Kropschot, and J. H. Wilson, Phys. Rev. Letters **6,** No. 9, 452–453 (May 1961).

Proposed nomenclature for linear viscoelastic behavior, H. Leaderman and F. Schwarzl, Rheologica Acta **1,** No. 4/6, 674–676 (1961).

FM and SSB radiotelephone tests on a VHF ionospheric scatter link during multipath conditions, IRE Trans. Commun. Systems **CS–8,** No. 3, 183–186 (Sept. 1960).

Publications for which a price is indicated (except for Technical Notes) are available only from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

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